TISSUE BONDING AND SEALING COMPOSITION AND METHOD OF USING THE SAME

This is a continuation-in-part of Ser. No. 07/560,069, filed Jul. 27, 1990, now U.S. Pat. No. 5,209,776.

FIELD OF THE INVENTION

The present invention is directed to a composition adapted to bond separated tissues together or to coat tissues or prosthetic materials to enhance strength and water tightness preferably upon the application of energy and particularly to a composition which is activated by a laser to form a strong, biologically compatible bond or coating.

BACKGROUND OF THE INVENTION

All surgical disciplines are concerned with the repair of damaged tissues and vessels. Damage can be the result of direct trauma to the body or as part of a surgical procedure in which there is a separation of normally continuous tissue such as in vein or artery anastomoses. Regardless of the cause, proper repair of the tissue or blood vessel is an essential step in the positive outcome of surgery.

The joining of separated tissues has principally been performed by suturing or stapling in which the skilled hands of the surgeon stitch or staple the separated tissues together. This procedure not only requires significant skill but also is a slow, tedious process, particularly if extensive repair is required.

Suturing suffers from several other drawbacks which have complicated surgical procedures. First, leaks often develop at the ends of the joined tissues which can require resuturing. In addition, suturing itself is a trauma to the tissue which can cause additional damage and extend the healing period. Further there are occurrences of inflammation in vicinity of the sutures which can result in late failure of a repair or anastomosis.

As a result, efforts have focused on overcoming the difficulties associated with suturing by the development of sutureless repairs using surgical adhesives or glues which adhere to tissue surfaces and form a bond therebetween.

The most common tissue adhesive is fibrin adhesive or glue typically containing a concentrate of fibrinogen and thrombin as disclosed in U.S. Pat. Nos. 4,362,567, 4,414,976 and 4,909,251 and Canadian Patent No. 1,168,982. The adhesives require mixing immediately prior to application and react in a manner similar to the last stages of the clotting cascade to form a fibrin clot. The clot effects hemostasis, a cessation of bleeding. By virtue of the physical properties of a blood clot, a small amount of tensile strength is present in the clot. Fibrin glue has been used in a variety of surgical procedures for its hemostatic properties, biocompatibility and as a modest reinforcement of the strength or more commonly the watertightness of a repair. (See, for example, Dennis F. Thompson et al., "Fibrin Glue: A Review of its Preparation, Efficacy and Adverse Effects as a Topical Hemostat", *Drug Intell. Clin. Pharm.* vol. 22, pp. 946–952 (1988); and Richard L. Burleson et al., "Fibrin Adherence to Biological Tissues", *J. Surg. Res.* vol. 25, pp. 523–539 (1978).

Fibrin adhesive, however, has significant drawbacks which has prevented its commercial use in the United States. First, in order to prepare commercial quantities of fibrin adhesive the components must be obtained from pooled human blood. There is therefore the possibility of infection from agents such as Hepatitis "B", HIV virus and others. Particularly in the United States, the threat of infection has outweighed the benefits of obtaining commercial quantities of fibrin adhesive. As a result, the production of fibrin adhesive has been limited to quantities obtained from a patient's own blood to reduce the risk of infection. (See, for example, Karl H. Siedentop et al., "Autologous Fibrin Tissue Adhesive", *Laryngoscope* vol. 95, pp. 1074–1076 (September, 1985); Gidon F. Gestring et al., "Autologous Fibrinogen for Tissue-Adhesion, Hemostasis and Embolization", *Vasc. Surg.* vol. 17 pp. 294–304 (1983) and D. Jackson Coleman et al., "A Biological Tissue Adhesive for Vitreoretinal Surgery", *Retina* vol. 8 no. 4, pp. 250–256 (1988). These autologous procedures make the use of fibrin adhesive costly and time consuming and therefore of limited value.

Second, fibrin glue preparations suffer from poor tensile strength. Third, fibrin glue requires time consuming mixing of multiple reagents immediately prior to application. Finally, once the reagents are mixed the glue polymerizes, and its removal disrupts the tissue on which it has been applied.

Non-biological materials have been tried as surgical adhesives in an effort to reduce the risk of infection over adhesives obtained from pooled blood. Isobutyl-2-cyanoacrylate has been applied to separated tissues and has formed a solid watertight seal shortly after contact with the tissue. Khalid J. Awan et al., "Use of Isobutyl-2- Cyanoacrylate Tissue Adhesive in the Repair of Conjunctional Fistula in Filtering Procedures for Glaucoma", *Annals of Ophth.* pp. 851–853 (August, 1974). However, such adhesives have been criticized because they are irritating to tissues and difficult to apply. Andrew Henrick et al., "Organic Tissue Glue in the Closure of Cataract Incisions", *J. CATARACT REFRACT. SURG.* vol. 13, pp. 551–553 (September, 1987).

Thus, surgical adhesives have not been successful in replacing the suture as the primary means of tissue and vessel repair.

Another approach to sutureless tissue repair is tissue welding. Tissue welding involves the bonding of tissues together using an energy source such as a laser beam. Several types of lasers have been found useful for tissue welding including Nd:YAG, CO_2, THC:YAG and Argon. Julian E. Bailes et al., "Review of Tissue Welding Applications in Neurosurgery", *Microsurgery* vol. 8, pp. 242–244 (1987); Rodney A. White et al., "Mechanism of Tissue Fusion in Argon Laser-Welded Vein-Artery Anastomoses", *Lasers in Surgery and Medicine* vol. 8, pp. 83–89 (1988); Lawrence S. Bass et al., "Sutureless Microvascular Anastomoses using the THC:YAG Laser: A Preliminary Report", *Microsurgery* vol. 10, pp. 189–193 (1989), Masame Suzuki et al., U.S. Pat. No. 4,625,724, Jude S. Sauer U.S. Pat. No. 4,633,870; Douglas Dew, U.S. Pat. Nos. 4,672,969 and 4,854,320, each incorporated herein by reference.

Tissue welding has been performed on a variety of tissues. For example, a carbon dioxide laser has been used in nerve tissue repair as described in Julian E. Bailes et al., *Microsurgery.* Tissue welding has successfully repaired intestinal tissue. Semion Rochkind et al., "Low-Energy CO_2 Laser Intestinal Anastomosis: An Experimental Study" *Lasers in Surgery and Medicine* vol. 8 pp. 579–583 (1988).

The use of lasers to directly weld tissues can eliminate about two-thirds of the time needed to repair damaged